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BOOK REVIEW

Modelling of Complex Systems
(IIT Kanpur series of Advanced Texts)
edited by J K Bhattacharjee and A K Mallik
Narosa Publishing House · New Delhi-Madras-Bombay-Calcutta-London (1997)
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A few years back, Paul Davies remarked in an introductory overview on emerging areas of new physics that there are really three 'ultimate frontiers of physics–the very small, the very large and the very complex'. While the underlying laws of nature for the first two are now wellknown, the systematic study of complex systems is relatively new in physical sciences. We owe a great deal to the development of high speed computers for the advent of this new science enabling us to model complex phenomena which were almost beyond the scope of any traditional analytic description so far. The present edited monograph under review is a collection of a number of articles bringing together such issues at a text level meant for advanced undergraduate students of various disciplines, such as, physics, chemistry, mechanical engineering, electrical engineering and civil engineering.

The range of complex phenomena is vast and almost all-pervading. It is sometimes hard to define what is simple ? Any macroscopic system with Avogadro number of atoms or molecules as its constituents by its very nature is complex. Nevertheless, we now understand how the infinite degrees of freedom behave on an average or in a cooperative manner by organizing themselves in a very special way under special circumstances. These developments have come a long way in thermal physics and low temperature physics. But the development of mathematical theory of dynamical systems in fifties and sixties and subsequent advances in dissipative systems in late seventies have led us to believe that even systems with two degrees of freedom can be erratic to the extent that an observation of a few swings can not tell us what will be its future motion after ten swings. This erratic behaviour is termed as chaos. Thus even with Newtonian determinism, the motion is not predictable. What is remarkable, however, is that there remains an underlying mathematical order which expresses itself through some universal scaling relations applicable to a wide range of phenomena where nonlinearity prevails. The related development heralds the beginning of dynamical system theory which has radically revised many of our traditional beliefs and ideas.

The object of the present volume is to give an overview of these complex phenomena in terms of simple models. The first chapter (Bhattacharjee) provides the basics of the theory of dynamical systems with essential properties of maps and flows and the features of universality with the help of simple renormalization group approach. This serves as an introduction for the subsequent chapters dealing with nonlinear mechanical vibrations (Mallik and Ravindra), chaos in chemical systems (Sathyamurthy), complex seismic behaviour of buildings (Murty). The chapter (Bhattacharjee) on several kinds of hydrodynamic instabilities specifically deals with infinite degrees of freedom in terms of partial differential equations as a starting point and then make use of finite mode truncation approaches to capture the essential details of instabilities within a very low dimensional phase space. It has been recognized that chaos and self-organization are deeply interrelated in several situations. The article (Chowdhury) on pattern formation in complex fluids addresses such aspects to demonstrate the formation of domains of ordered regions and their growth in time from a disordered initial state. The complexity here is associated with multiple scales in the energy landscape. In another contribution (Maity), the standard methodology of statistical mechanics and the concept of spin glass have been applied to neural network problem to understand a very complex process–the learning, in terms of a simple model. The direct method of analysis of a complex system with very large degrees of freedom relies on straightforward implementation of suitable computational scheme. Based on Monte-Carlo computation, a functional integral approach with applications to calculation of statistical mechanical partition functions, equilibrium average, Gutzwillar trace formula *etc* have been outlined (Singh and John). Although, strictly speaking, predictability is lost in a chaotic phenomenon, suitable nonlinear state space model has been reconstructed for prediction purpose, on the basis of time series analysis in a variety of phenomena, such as fluid flow, sunspot, epidemics, electroencephalogram etc. The models, applications and predictions in this context has been discussed in an article (Kumar and Mullick).

The contributions in this volume thus cover a wide range of disciplines. The articles are, in general, thorough and lucid in presentation, although some of them go somewhat beyond what is expected at a text level. Some addition on the basic concepts of fractals and self-organized criticality would have made it more richer. The book contains enough material for an undergraduate course on nonlinear dynamics and the related allied phenomena. This is supplemented by many useful references. The editors have done an excellent job. The volume, no doubt will be a welcome addition to any science library.

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